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Mr. Philip H. Mook, Jr.
Western Execution Branch Chief
Air Force Civil Engineer Center
United States Department of the Air Force

SUBJECT: 11/17/2016 Letter re: Former Williams AFB Site ST012, Liquid Fuels Storage Area
Path Forward; 11/30/2016 Letter from TerraTherm

Dear Mr. Mook:

Thank you for your letter inquiring about the path forward for the ST012 Site "Site". We acknowledge and appreciate the AF's ongoing efforts to contain and characterize the extent of remaining LNAPL contamination and agree that progress is being made. We look forward to the startup of the new hydraulic containment system in January. Based upon our review of the data being collected, maintaining hydraulic containment will be critical to the future protectiveness of the remedy going forward.

We also received a copy of the November 30, 2016 letter from John Biershank of TerraTherm requesting access to the Site to remove their remaining Steam Enhanced Extraction (SEE) system equipment; *"given the SEE system has been essentially dismantled, AMEC and the Air Force could not restart SEE activities without reconstructing the SEE system and essentially beginning the mobilization process all over again."* In furtherance of continued progress, EPA and ADEQ are in agreement with TerraTherm's request to allow them to remove their equipment from the site.

At this time the path forward for ST12 is complicated by many factors and uncertainties that must be resolved before we can understand and reach agreement upon the most appropriate next steps. The data AF is collecting now will help delineate the lateral extent of contamination as it currently exists, and sentry wells are being installed to enable us to evaluate the success of the hydraulic containment. In our comments on the Field Variance for characterization, we also requested additional wells or borings to be located closer to the known contaminated area to reduce the uncertainty in the extent and mobility of contamination. These are still needed to locate and reduce uncertainty in the estimate of remaining LNAPL mass, but have not yet been added to the field variance for characterization.

As the 2013 Record of Decision Amendment (RODA) specified attainment of remedial action objectives within 20 years, we now need to understand how expectations for the longevity of this remedy have changed given the current site conditions. We also need to understand the feasibility and cost/benefit of the options going forward. At the time of the RODA signature, it was not anticipated that there would be large quantities of remaining LNAPL, especially untreated mobile LNAPL still rich in benzene and BTEX compounds, ~~would be remaining at the Site following termination of SEE. The fact that a large quantity of LNAPL remains at the site which would requires a re-assessment of our remedial progress and a critical evaluation of the path forward, ongoing hydraulic containment.~~

When the ST12 remedy was first described to the agencies, it was assumed that SEE would be employed to remove almost all of the LNAPL source in order to create optimal conditions for Enhanced Bioremediation (EBR) to degrade dissolved phase residual contaminants. Given that the construction costs associated with thermal technologies significantly outweigh the operational costs, thermal remedies are almost always run until the contaminant source is completely removed, as the industry standard for this technology. If ~~essentially almost all~~ of the LNAPL source material had been removed by SEE, there would have been no need for further hydraulic containment following SEE, hence, it was not included in the RODA. This understanding is documented in the January 4, 2013 draft proposed plan (attached) which described the remedy as follows: *"After most of the LNAPL is removed by SEE, the remedial action would transition to enhanced bioremediation"* This language was changed in subsequent documents to specify performance criteria for the SEE system which the agencies believed were intended to signal when ~~essentially all most~~ of the LNAPL had been removed. However, as we have previously explained, the performance criteria specified in the Remedial Design/Remedial Action Work Plan (RD/RAWP) had not been consistently attained at the time the SEE system was terminated and dismantled over regulatory agency objections.

The remaining mass estimates in the RD/RAWP Addendum 2 for EBR indicate that the SEE may have only targeted half of the LNAPL in the subsurface, and in addition to this, LNAPL remains in the thermal treatment area due to premature remedy termination. An accurate estimate of remaining LNAPL mass and BTEX concentrations residing within the LNAPL mass within specific locations and depths is critical to 1) resolve uncertainties of amendment mass loading required for successful implementation of EBR, 2) enable specific areas and depth zones to be targeted for treatment 3) evaluate the impact of amendment upon groundwater quality, 4) estimate the anticipated timeframe to meet remedial action objectives, and 5) define milestones for monitoring EBR remedy success against baseline conditions. Appropriate and agreed-upon baseline conditions need to be established in order to be able to monitor remedy performance. AF's responses to agency comments provided to date have not provided this information and have not resolved these concerns.

Your letter of November 17, 2016 expresses concerns that elevated post steam temperatures are necessary for successful Enhanced Bioremediation (EBR) implementation as *"partially dependent upon taking advantage of the increased solubility and dissolution of contaminants of concern (COCs) from LNAPL occurring at elevated temperatures"*, and, *"increased anaerobic degradation at the higher temperatures is currently establishing microbial populations that can be further enhanced for bioremediation of COCs. If extended extraction is used for hydraulic*

Commented [DE1]: Carolyn, I believe your intent here was that an honest evaluation of these items would make it clear that EBR is not appropriate for the remaining mass, but I agree with Steve et al that it can give the impression that EBR is applicable to LNAPL source zones. I recommend changing these to specify a focused feasibility study to evaluate the options for additional source control. After the source is eliminated, then we evaluate EBR for the remaining dissolved phase.

Commented [s2]: This statement implies EBR is applicable to NAPL zones and may not be appropriate. The next statement is more accurate wherein treatment method is left undefined

Commented [s3]: Same as above

Commented [s4]: EBR should be deleted and left undefined as to the method of remedy. The final paragraph recommends a FFS so we shouldn't mention specifics here.

containment instead of establishing EBR reagent distribution, deterioration of conditions favorable to the anaerobic EBR approach will occur due to introducing cooler groundwater and higher dissolved oxygen levels." While elevated temperatures may enhance bacterial growth, this is generally true for only a narrow range of temperatures. Temperatures above this narrow range are not favorable for microbial survival. In addition, the rate of mass loading of sulfate amendment can also affect the degradation rate and would need to be carefully monitored and controlled. We did not see acknowledgement or preparations to address these considerations in the RD/RAWP Addendum 2. (Please see attached journal article, *Engineered Anaerobic Bio-Oxidation Systems for Petroleum Hydrocarbon Residual Source Zones with Soluble Sulfate Application* Suthersan et al., *Ground Water Monitoring & Remediation*, 31(3):41-46, 2011)

Recently, during the 5 Year Review inspections for the Lawrence Livermore site where a smaller 100,000 cubic yard thermal application was implemented it was documented that subsurface temperatures within the former treatment area still remain elevated by a few degrees above the surrounding aquifer twenty years after termination of thermal treatment. At the Livermore site, the thermal remedy was run to completion and remedial action objectives were attained (without the need for follow-on EBR—Eva is this correct?) In comparison, the 410,000 cubic yard SEE application at ST12 is the largest and deepest ever implemented and can be expected to remain at elevated temperatures for many years, even with ongoing extraction for containment. The same conditions that enhance solubility and dissolution of contaminants conducive to EBR also increase the mobility of contaminants; which are the most significant concern the regulatory agencies have for maintaining the future protectiveness of the remedy. Contaminants cannot be allowed to migrate away from the site and create a more extensive groundwater plume.

Commented [DE5]: This was a demonstration project -

Based upon our analysis of the most recent soil boring and groundwater data, migration of the dissolved phase already appears to be occurring. For example, the data from the existing sentry wells provided on November 30, 2016 indicated increasing benzene concentrations at W-36 which doubled between 8/31 and 11/1, and is now 1600 ug/l. We also note LNAPL appearance in monitoring wells has diminished because the driving pressure gradient to move the LNAPL into wells (i.e., drawdown) has diminished. Even so, based on from the November 11, 2016 weekly report several interior Thermal Treatment Zone wells in the Lower Saturated Zone (LSZ) which previously were shown to be free of LNAPL following SEE treatment now have over a foot of LNAPL in them. Numerous SEE wells, including former steam injection wells in both the UWBZ and LSZ, have experienced multiple LNAPL removal events. LNAPL appearance in monitoring wells has diminished because the driving pressure gradient to move the LNAPL into wells (i.e., drawdown) has diminished, not because LNAPL has been depleted from the subsurface. These observations is indicates that LNAPL within the treatment area was not recovered and could migrate off site if not contained. Numerous recent characterization borings, including CZ-23, UWBZ-37, LSZ-43, LSZ-45, LSZ-46, UWBZ28/LSZ51, UWBZ33/LSZ48, SB19/LSZ61, LSZ44, had PID readings or analytical results indicative of contamination exceeding the MCL for benzene, and it is not clear that the containment system currently being constructed will be adequate contain the plume in these areas. Once the containment system is operating, an assessment of the capture zone should be undertaken, and necessary improvements to the system must be made.

The EBR application as described in the Addendum 2 RD/RAWP is a much larger effort than was anticipated at the time of the 2013 RODA signature. The large amount of amendment proposed to be injected to degrade the remaining LNAPL cannot be permitted to degrade water quality downgradient of the site and must therefore also be contained. It does not appear that the interim containment system now being constructed has been designed to be capable of also treating extracted EBR amendment or the arsenic contaminant it contains; the treatment system will require an upgrade to treat the extracted amendment before EBR application could begin. If AF is concerned that cooler water from outside of the Site should not enter the EBR treatment area, the containment system should be reconfigured to extract from perimeter wells to meet that objective. The costs of long term containment should also be weighed against performing additional SEE to eliminate the bulk of LNAPL as was intended under the current remedy specified in the 2013 RODA.

Commented [DE6]: This again makes it sound like we might agree to EBR of LNAPL.

The efficacy of EBR to treat such a large mass of remaining LNAPL is questionable and unprecedented in that this has never been attempted anywhere else on a comparable scale, and has not even been bench or pilot tested at this site. LNAPL cannot be expected to directly biodegrade; the LNAPL components must first dissolve into the aqueous phase for degradation to occur. The modelling effort employed in the RD/RAWP Addendum 2 does not account for mass transfer limitations of dissolution. The attached paper, *Engineered Anaerobic Bio-Oxidation Systems for Petroleum Hydrocarbon Residual Source Zones with Soluble Sulfate Application Suthersan et al., Ground Water Monitoring & Remediation, 31(1):45-49, 2011* states "The presence of a NAPL source zone leads to inherent uncertainty with regard to achieving remediation endpoints as the NAPL extent and structure (i.e., surface area) is unknown." Furthermore, "The presence of a smear zone, where porosity is consumed to varying extents by residual separate-phase PHCs, can present a challenge to effective reagent delivery." Currently, the smear zone at ST12 extends nearly 100 feet from the water table to 230 feet² below ground surface and it cannot be expected that it can be treated adequately by amendment injection.

It has also come to our attention that AF's Preliminary Assessment for Perfluorinated Compounds (PFCs PA) identified the area of ST12 as the site of at least 2 spills where PFC firefighting foams were applied and allowed to soak into the ground. Although we currently have no data to assess the situation, a follow on Site Inspection has been recommended. EPA deferred remedy protectiveness for ST12 on the 2016 Five Year Review pending resolution of data gaps for PFCs. This uncertainty also contributes to the difficulty in determining the most appropriate path forward for ST12 at this time, as the ultimate remedy needs to be compatible with and address all of the potential concerns at the site. For example, it was recently reported that perfluoroalkyl fatty acids (PFFA) precursors as found in firefighting foams may biotransform under aerobic conditions but not under anaerobic conditions such as currently proposed for the Site. (AECOM /Arcadis NEWMOA webinar presentation November 11, 2016.)

We are attaching (or will follow up?) with a formal reply to the responses to agency comments on the RD/RAWP Amendment 2 work plan. We hope that AF appreciates the technical complexity of the problem now to be solved. Given the substantial technical considerations, uncertainties, implementability, remedy effectiveness and cost/benefit considerations, we believe a focused RI/FS is warranted to resolve these issues if the AF chooses not to employ additional SEE to remove the remainder of LNAPL at the site. In the interim we also recommend

Commented [DE7]: I think we should totally put these on hold. We can't pretend to finalize a work plan for the EBR before the remaining LNAPL is addressed.

aggressive extraction to remove as much mobilized LNAPL as possible and prevent the spread of groundwater contamination at the site.

Sincerely,

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Quality

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cc: Cathy Jerrard, AFCEC
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